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Morphological changes of the lateral meniscus in end-stage lateral compartment osteoarthritis of the knee

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SUMMARY

Objective: The aim of this study was to evaluate the morphological changes of the lateral meniscus in end-stage lateral compartment osteoarthritis (OA) of the knee.

Methods: One hundred fifty-eight knee joints from 133 patients that subsequently underwent total knee joint arthroplasty from January 2008 to December 2009 were enrolled. There were 26 men and 107 women. Their ages ranged from 56 to 81 (mean 67.4 ± 6.5 years). All study participants had complete obliteration of the lateral joint space identified by weight-bearing radiography. Meniscal position was assessed by measuring meniscal subluxation and meniscal height. The meniscal morphology was assessed using a modification of the whole-organ magnetic resonance imaging score (WORMS). The frequency of different meniscal morphology and their respective positions was calculated.

Results: The predominant type (42.4%, 53.8% and 52.5% in the anterior horn, mid-body and posterior horn, respectively) of abnormal meniscal morphology was a complete maceration/destruction or complete resection. The anterior horn of non-macerated lateral meniscus was more subluxed than that of the non-macerated medial meniscus in patients with lateral OA.

Conclusion: This study suggests that the lateral meniscus in persons with end-stage lateral OA are mostly macerated or destroyed. Also, unlike isolated end-staged medial compartment OA, the anterior horn of the lateral meniscus in isolated end-stage lateral OA is commonly affected.

Introduction

Structural changes in knee osteoarthritis (OA) are characterized by significant cartilage loss, subchondral sclerosis, osteophytosis, subchondral cysts, meniscal degeneration, and other intraarticular or extraarticular soft tissue abnormalities[1–5]. In addition to extensive investigations of the biology and genetic etiology of OA[6–9], investigators have attempted to describe the morphological characteristics associated with such structural changes[10–14]. Among them, the meniscus, as one of the soft tissues most prominently involved in OA etiopathogenesis, has been evaluated based on its integral role in knee function[15–17]. Several studies have shown that both meniscal subluxation and meniscal tears are common not only in knee OA, but are particularly frequent in knees with radiographic knee OA and appear to be related to the degree of joint space narrowing (JSN) on plain radiographs[11,15,16,18,19]. Based on prior reports and existing dogma[11], the common consensus is that advanced stage OA of the knee, with complete loss of either the medial or lateral compartment joint space on radiographs, might be associated with completely macerated/destroyed meniscus and hyaline cartilage. However, a previous study detected no correlation between radiological and morphological changes of the medial meniscus in end-stage medial OA[20], in which a hypertrophied meniscus was the most prevalent finding. Another recent study showed that OA knees have thicker menisci than those of non-OA knees[21]. In terms of lateral tibiofemoral (TF) arthritis, to date, there is one study comparing the prevalence of lateral TF OA in Asian and Western populations[22] suggesting that Asian knees have more lateral TF OA. The

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explanation for this lateral TF OA increase in Asian knees is not currently known. Furthermore little is known about the morphological and positional changes of the lateral meniscus in patients with advanced lateral OA. Therefore, the aim of this study was to examine the morphological and positional changes of the lateral meniscus in patients with advanced lateral compartment OA.

Materials and methods

Study participants

The research design used in this study was a consecutive series of patients presenting with end-stage lateral TF OA to an orthopedic specialty hospital in South Korea. A total of 143 potential patients participated in this study. All potential patients presented with lateral compartment OA. A series of knee radiographs (weight-bearing posteroanterior radiographs, weight-bearing 30° posteroanterior, lateral, and skyline views) were obtained for each patient to determine whether advanced lateral TF compartment radiographic OA was present. The radiographs were graded using the Kellgren–Lawrence (K&L) grading scale[23] and scored for lateral JSN on a scale of 0 (normal)–3 (total loss of the joint space) with the help of the Osteoarthritis Research Society International (OARSI) atlas[24] by two experienced clinicians (SHH and WJL) with 7 and 6 years of musculoskeletal radiology experience respectively. Patients with complete lateral joint space obliteration (K&L = 4 and lateral JSN = 3) on the weight-bearing posteroanterior radiograph were eligible for this study. The inter-rater reliabilities of KL and OARSI grading were determined by calculating the intraclass correlation coefficients (ICCs), which were 0.96 and 0.95, respectively. Ten patients were excluded due to diagnoses of secondary OA (i.e., OA associated with fracture, prior associated arthroscopic or open surgery of target knee, or another disease processes), simultaneous medial compartment OA with medial JSN, and systemic inflammatory arthritis (e.g., rheumatoid arthritis or gout), based on medical records. Patients without contraindications to magnetic resonance imaging (MRI) underwent MRIs of their abnormal knee joints. Finally, a total of 158 knee joints among 133 patients were included in this study from January 2008 to December 2009. The study protocol was approved by the hospital ethics committee at our institution and all patients provided written informed consent to use their anonymized data.

Limb alignment assessments

The degree of valgus deformity was measured as the femorotibial angle (FTA) by two experienced raters (SHH, WJL) using a standing long limb radiograph. FTAs were measured by drawing a line along the axis of the femoral shaft to intersect the corresponding line drawn through the tibial shaft. The readers were blinded to MRI results during the assessment. The inter-rater reliabilities of the FTA measurements were determined by calculating the ICCs, which was 0.93.

MRI acquisition

Meniscus changes were assessed using a 1.5 T MRI system in the sagittal and coronal planes with spin-echo (proton density weighted acquisition) and fast scan (T2-weighted images) techniques. Sagittal and coronal spin-echo proton density weighted acquisition images were acquired using the following parameters: 1800/15/2 (TR/TE/NEX), slice thickness 4 mm, inter-slice gap 0.4 mm for coronal images and 0.3 mm for sagittal images, slice thickness 3 mm, and matrix 256 × 256. T2-weighted images were also acquired using the following parameters: 3700/100/2 (TR/TE/NEX), slice thickness 4 mm, inter-slice gap 0.4 mm for coronal images, and a slice thickness of 3 mm with an inter-slice gap of 0.3 mm for sagittal images.

MRI interpretations

The anterior and posterior horns and mid-bodies of menisci were examined for (1) meniscal morphology and (2) meniscal position (Figs. 1 and 2). During assessment, the readers were blinded to radiographic results, patient symptoms, patient age, and other clinical data. Meniscal morphology (integrity) was measured independently by two experienced observers (SHH, WJL), and the overall ratings were determined by consensus when necessary. The morphology was assessed at each portion of the meniscus, using a modification of the whole-organ magnetic resonance imaging score (WORMS) assessment system[25]. According to the modifications reported in a previous study[20]: 0 = intact, 1 = minor radial tear or parrot-beak tear, 2 = non-displaced tear, 3 = displaced but no tear, 4 = displaced tear or partial resection, 5 = hypertrophied and displaced, 6 = hypertrophied displaced tear, and 7 = complete maceration/destruction or complete resection (Fig. 1). The meniscal integrities of the anterior and posterior horns of the menisci were measured in the sagittal and coronal planes, in which the meniscal morphology was best observed. The mid-body height was measured where the medial and lateral tibial spine volumes were maximal[11,12,17]. "Hypertrophy" was considered to be present when the height of the lateral meniscus was 2 mm greater than that of the medial meniscus, regardless of medial meniscus width, using reference values of the normal meniscus height in which those of the lateral meniscus are normally smaller than the medial meniscus[17]. The inter-rater reliability of meniscal morphology ratings was 0.87 (kappa) for meniscal morphology at the anterior horn of the lateral meniscus, 0.80 at the mid-body of the lateral meniscus, and 0.86 at the posterior horn of the lateral meniscus.

Two experienced observers (SHH, WJL) independently measured the meniscal position; mean values were used for analysis. Meniscal position was assessed by measuring the meniscal subluxation and height of each knee (Fig. 2). To determine meniscal height, the anterior and posterior horns of the menisci were measured in the sagittal plane, which allowed the best visualization of the greatest meniscal size. The mid-body height was measured in the coronal plane, where the medial and lateral tibial spine volume was maximal. The meniscal height was measured at the most peripheral edge of each meniscus, regardless of whether the meniscus was "in place", subluxed or extruded. To determine meniscal subluxation, anterior subluxation of the anterior horn of the medial and lateral meniscus was assessed in the area where the subluxation was most prominent through multiple sagittal slices. Lateral subluxation of the mid-body of the lateral and medial subluxation of the medial meniscus were measured where the volumes of the medial and lateral tibial spine were greatest. Posterior subluxation of the posterior horn was not measured, because this could not be performed accurately in the sagittal plane. Meniscal subluxation and meniscal height could not be measured for completely macerated or destroyed menisci (Fig. 2) and were handled as missing values and 0 mm, respectively, for statistical analysis. The inter-rater reliabilities of the meniscal position measurements were determined by calculating the ICCs. An ICC of 1 suggests perfect reliability, and ICCs > 0.75 and <0.4 are generally considered to represent excellent and poor reliability, respectively. For the cases that could be measured, the ICCs for the meniscal height and meniscal subluxation were the height at the anterior horn 0.74, mid-body 0.81, and posterior horn 0.80; anterior

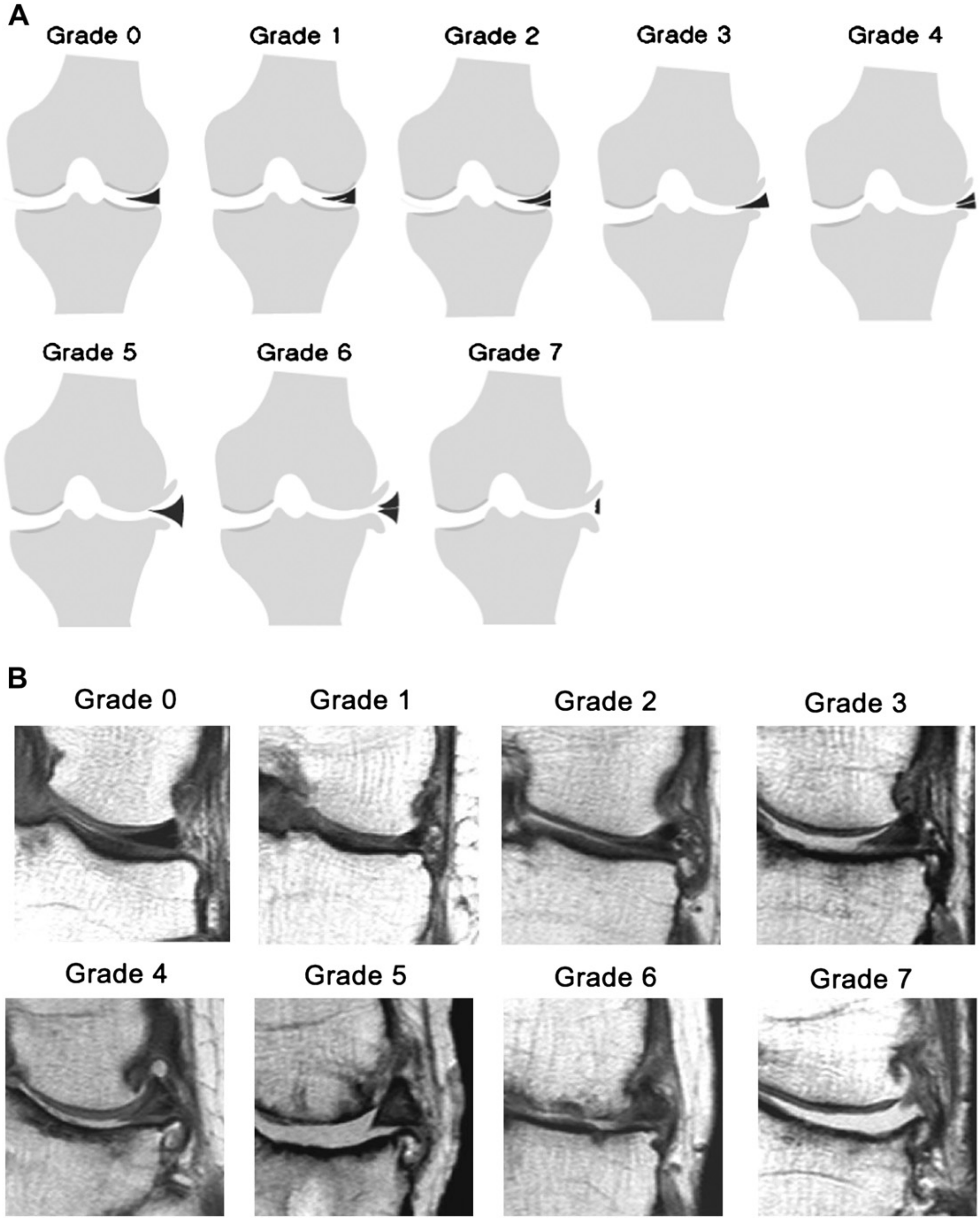

Fig. 1. A, B. The modification of the WORMS assessment method[24]. Schematic drawing (A) and MRI findings (B) are representative of the global meniscus scoring system. 0 = intact, 1 = minor radial tear or parrot-beak tear, 2 = non-displaced tear, 3 = displaced but no tear, 4 = displaced tear or partial resection, 5 = hypertrophied displaced, 6 = hypertrophied displaced tear, 7 = complete maceration/destruction or complete resection "Hypertrophy" >2 mm larger than MM.

subluxation at the anterior horn 0.85, and lateral subluxation at the mid-body 0.84.

Statistical analysis

First, the frequency of meniscal morphology for each portion of the meniscus was determined. Second, the medial meniscus height and subluxation in cases with non-macerated lateral meniscus were compared with those in cases with macerated lateral meniscus using the Student's *t*-test. Third, the lateral meniscus height and subluxation in cases with non-macerated lateral meniscus were compared to those of the medial meniscus using the paired sample *t* test at each meniscal portion, including the anterior horn, mid-body, and posterior horn. The differences in FTA valgus angle were evaluated according to each meniscal type at the anterior, mid-body and posterior horn by one-way analysis of variance (ANOVA) with *post-hoc* comparisons (Tukey's test). For height and subluxation in cases with macerated lateral meniscus, where each value was unmeasurable, comparisons with cases that had non-macerated meniscus could not be performed. Correlations between the body mass index (BMI), FTA, and gender with meniscus parameters, such as meniscal height and meniscal subluxation, were carried out using correlation coefficients (Spearman) for each knee. If $r < 0.3$, it was regarded as week

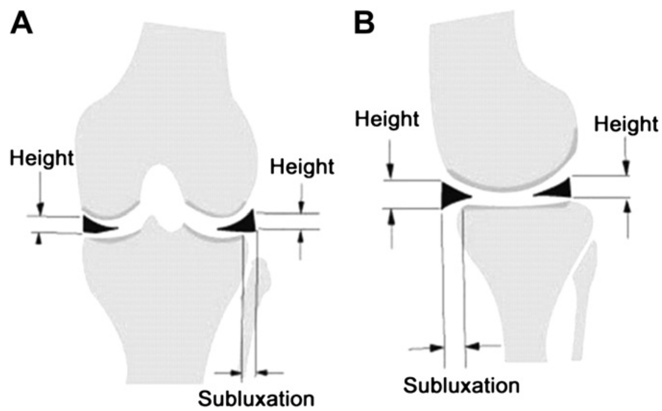

Fig. 2. A, B. Meniscal position was assessed by measuring meniscal subluxation and height for each knee. To determine the meniscal height, the anterior and posterior horns of the menisci were measured in the sagittal plane, which allowed for the best visualization of the greatest meniscal size. The mid-body height was measured in the coronal plane, where the medial and lateral tibial spine volume was maximal. (A) The meniscal height was measured at the most peripheral edge of each meniscus, regardless of whether the meniscus was "in-place", subluxed or extruded. To determine the meniscal subluxation, the anterior subluxation of the anterior horn of the medial and lateral meniscus was assessed in the area where the subluxation was most prominent, based on multiple sagittal slices. (B) Lateral subluxation of the mid-body of the lateral and medial subluxation of the medial meniscus was measured where the volume of the medial and lateral tibial spine was greatest. *Posterior subluxation of the posterior horn was not measured, because this could not be performed accurately in the sagittal plane. For the menisci that were completely macerated or destroyed, meniscal subluxation and meniscal height could not be measured.

correlation, if $r > 0.3$ and <0.7, it was regarded as intermediate correlation, and if $r > 0.7$, it was regarded as strong correlation between variables.

All analyses were performed using SPSS 11.0 (SPSS Inc., Chicago, IL, USA). P values of 0.05 or less were considered significant.

Results

Twenty-six patients were men and 107 were women (ages ranged from 56 to 81, mean age 67.4 ± 6.5 years). The average patient weight was 60.3 ± 9.6 kg (range; 42–93), average BMI was 25.2 ± 3.4 (range; 17.2–32.4), and average height was 154.5 ± 8.5 cm (range; 140–173).

Meniscal morphology

The meniscal morphology for the study sample is summarized in Table I. The most frequent morphology observed was complete maceration or complete resection (grade 7) in the anterior horn (42.4%), mid-body (53.8%), and in the posterior horn (52.5%) of the lateral meniscus.

Meniscal position

The mean values for subluxation and height of the medial and lateral meniscus for the study patients are summarized in Table II. The anterior horn of the medial meniscus in cases with macerated lateral meniscus showed significantly more subluxation than in cases with non-macerated lateral meniscus. The height of the mid-body of the medial meniscus in cases with macerated lateral meniscus was significantly smaller than that in non-macerated lateral meniscus.

In the analysis of cases with non-macerated lateral meniscus only, the anterior horn and mid-body of the lateral meniscus showed significantly more subluxation than that of the medial meniscus in the same cases. In addition, the height of the anterior horn and mid-body of the lateral meniscus were significantly smaller than the medial meniscus in the same cases.

FTA angle

The FTA valgus angle was not related to meniscal morphological grade at the anterior and posterior horn. However, in terms of the mid-body, the FTA angle showed differences between grade 5 and grade 2 ($P = 0.030$), between grade 5 and grade 4 ($P = 0.012$) and between grade 5 and grade 6 ($P = 0.018$) (Table III).

Gender was not correlated with meniscal position or with FTA except subluxation of the mid-body of the medial meniscus (Table IV). BMI was not correlated with meniscal position or FTA except subluxation of the mid-body of the lateral meniscus ($r = 0.232$, $P = 0.003$), subluxation of the anterior horn of the medial meniscus ($r = 0.223$, $P = 0.005$), and subluxation of the mid-body of the medial meniscus ($r = 0.257$, $P = 0.001$).

Discussion

The results of this study demonstrate that the majority of patients had completely macerated or destroyed meniscus with end-stage lateral OA of the knee; in contrast to our previous study[20] that showed that most cases with advanced medial OA had hypertrophied medial meniscus. These findings suggest that degenerative changes of the lateral meniscus might progress to meniscal tears, which may ultimately lead to complete destruction, unlike the changes we had previously found in the medial meniscus. According to the modified WORMS classification, the predominant type of lateral meniscus injury in end-stage lateral OA was grade 7 (complete maceration/destruction or complete resection) followed by grade 4 (displaced tear or partial resection).

In terms of dimensional changes of the anterior horn of the lateral meniscus, the proportions of grade 4 and grade 7 (grades 3; 4; 5; 7 = 13.9%; 32.9%; 2.5%; 42.4%) were higher and of grade 3 and grade 5 were lower, compared to end-stage isolated medial OA (grades 3; 4; 5; 7 = 20.4%; 15.6%; 30%; 0%). Tears of the anterior horn of the lateral meniscus were very common findings (82.9%, 131/158 cases) in lateral compartment OA, unlike the anterior horn of the medial meniscus in end-stage isolated medial OA[20], with an incidence of 47.9% (80/167 cases). Regarding the mid-body of the lateral meniscus, the proportion of grade 7 (53.8%) was much higher than for end-stage medial OA (7.2%). The overall incidence of mid-body tears of the lateral meniscus was 94.3% (149/158 cases) in

Table I
Meniscal morphology at each portion of the lateral meniscus assessed by a modified WORMS method

	Grade 0 (%)	Grade 1 (%)	Grade 2 (%)	Grade 3 (%)	Grade 4 (%)	Grade 5 (%)	Grade 6 (%)	Grade 7 (%)	Total (%)
Ant. horn of LM	1 (0.6)	0	3 (1.9)	22 (13.9)	52 (32.9)	4 (2.5)	9 (5.7)	67 (42.4)*	158 (100)
Mid-body of LM	1 (0.6)	1 (0.6)	6 (3.8)	4 (2.5)	50 (31.6)	4 (2.5)	7 (4.4)	85 (53.8)*	158 (100)
Post. horn of LM	1 (0.6)	0	1 (0.6)	5 (3.2)	63 (39.9)	2 (1.3)	3 (1.9)	83 (52.5)*	158 (100)

Grade 0 = intact, 1 = minor radial tear or parrot-beak tear, 2 = non-displaced tear, 3 = displaced but no tear, 4 = displaced tear or partial resection, 5 = hypertrophied displaced, 6 = hypertrophied displaced tear, 7 = complete maceration/destruction or complete resection.

* Predominant type in each portion.

Table II
Meniscal position and meniscal height for each region of the meniscus, as determined by MR imaging

		No. of knees (n, total n = 158)	Subluxation of LM Mean ± standard deviation (SD) [95% confidence interval]	Subluxation of MM Mean ± SD [95% confidence interval]	Height of LM Mean ± SD [95% confidence interval]	Height of MM Mean ± SD [95% confidence interval]
Macerated LM (grade 7)	Ant. horn	67	Not measured	2.77 ± 2.55 mm (0–12.31)‡ [2.14–3.39]	Not measured	5.38 ± 1.10 mm (3.44–8.50)§ [5.11–5.64]
	Mid-body	85	Not measured	2.26 ± 1.98 mm (0.0–7.91) [1.83–2.69]	Not measured	5.92 ± 1.60 mm (2.93–9.67)‖ [5.65–6.19]
	Post. horn	83	Not measured	Not measured	Not measured	5.56 ± 1.40 mm (2.5–8.9) [5.25–5.87]
Non-macerated LM (remainder)	Ant. horn	91	6.45 ± 3.11 mm* (0–12.01) [5.80–7.10]	1.30 ± 1.72 mm‡ (0–6.74) [0.94–1.66]	5.41 ± 1.98 mm (2.03–11.15) [4.99–5.82]	6.35 ± 1.71 mm†,§ (3.01–7.91) [5.99–6.71]
	Mid-body	73	5.27 ± 3.37 mm* (0–14.94) [4.48–6.06]	2.44 ± 2.14 mm (0–7.32) [1.94–2.94]	6.03 ± 1.88 mm (0.25–11.70) [5.59–6.47]	7.05 ± 1.83 mm†,‖ (3.14–12.89) [6.62–7.48]
	Post. horn	75	Not measured	Not measured	5.66 ± 1.63 mm (3.01–9.08) [5.28–6.04]	5.89 ± 0.92 mm (4.1–7.62) [5.68–6.10]

MM medial meniscus, LM lateral meniscus, n total number of knee [95% confidence interval], Mean BMI: 25.8 ± 3.36 (range: 17.92–32.39).
*$P = 0.001$.
†$P = 0.001$.
‡$P = 0.0001$.
§$P = 0.003$.
‖$P = 0.002$.

comparison to 95.7% (160/167 cases) of the medial meniscus in the mid-body of end-stage medial OA[20].

For the posterior horn, the proportion of grade 6 (1.3%) was low and of grade 7 (53.9%) was much higher, compared to end-stage medial OA (grades 6, 7 = 83.8%; 0.5%). The overall incidence of post horn damage of the lateral meniscus was 94.9% (150/158 cases) in comparison to 98.8% (165/167 cases) of the posterior horn of the medial meniscus in end-stage OA[20]. These findings indicate that most lateral menisci in persons with end-stage lateral OA are predominantly macerated. However, all parts of the meniscus were not completely macerated; 57.6% (91/158 cases), 46.2% (63/158 cases) and 47.5% (75/158 cases) of each portion of the lateral meniscus were not macerated. Therefore, although the existing dogma appears to be correct in suggesting that in the vast majority of persons with end-stage OA the meniscus is destroyed/macerated, it is important to consider that the entire lateral meniscus is not affected by the same mechanism. In addition, various factors influencing mechanisms associated with lateral OA remain unknown.

Limb alignment was associated with the meniscal morphology of the mid-body of the lateral meniscus, which had a high valgus alignment of 17.7 ± 3.7° in grade 5 relative to other grades. These findings are different from those of end-stage medial OA that we published previously, which limb alignment was not associated with meniscal morphology[20]. However, as the number of grade 5 cases was small, further studies with larger numbers of cases might be needed to conclude whether there are definite differences between FTA and meniscal morphology or not. In terms of meniscal position, both non-macerated and macerated lateral menisci were accompanied by subluxation of the medial meniscus of the same knee. In detail, the anterior horn and mid-body of the medial meniscus in cases with non-macerated lateral meniscus showed

Table III
Association between FTA and each meniscal morphology

Meniscus morphology	Anterior horn of lateral meniscus*		Mid-body of lateral meniscus†		Posterior horn of lateral meniscus‡	
	No. of knee	FTA mean ± SD [95% confidence interval]	No. of knee	FTA mean ± SD [95% confidence interval]	No. of knee	FTA mean ± SD [95% confidence interval]
0	1	8.15	1	0.5	1	0.5
1	0	–	1	2.8	0	–
2	3	11.8 ± 6.4 [−4.1 to 27.7]	6	7.2 ± 2.6 [4.47–9.93]	1	2.8
3	22	8.2 ± 4.5 [6.2–10.2]	4	13.0 ± 4.5 [5.84–20.16]	5	13.1 ± 5.8 [5.9–20.3]
4	52	8.0 ± 4.6 [6.72–9.28]	49	8.4 ± 4.5 [7.11–9.69]	62	8.8 ± 5.7 [7.35–10.25]
5	4	13.0 ± 9.8 [−2.59 to 28.59]	4	17.7 ± 3.7 [11.8–23.59]	2	16.3 ± 1.3 [4.62–27.98]
6	9	9.1 ± 7.0 [3.72–14.48]	7	7.0 ± 3.9 [3.39–10.61]	3	6.3 ± 0.9 [4.06–8.54]
7	66	10.6 ± 5.8 [9.17–12.03]	86	10.0 ± 5.9 [8.74–11.26]	84	9.7 ± 5.3 [8.55–10.85]
Total	158	9.4 ± 5.5 [8.54–10.26]	158	9.4 ± 5.5 [8.54–10.26]	158	9.4 ± 5.5 [8.54–10.26]

* Anterior horn: P-value (one-way ANOVA test): 0.067.
† Mid-body: P-value (one-way ANOVA test): 0.007, grade 5 vs grade 2 ($P = 0.030$), grade 5 vs grade 4 ($P = 0.012$), grade 5 vs grade 6 ($P = 0.018$) in *Post-hoc* test (Tukey test).
‡ Posterior horn: P-value (one-way ANOVA test): 0.113.

Table IV
Association between sex and meniscal subluxation, FTA

	Sex	No. of knees	Mean ± SD [95% confidence interval]	*P*-value
FTA	F	126	9.15 ± 5.36 [8.20–10.09]	0.267
	M	32	10.35 ± 5.89 [9.31–11.39]	
Subluxation of LM (ant. horn)	F	126	3.56 ± 3.93 [2.87–4.25]	0.335
	M	32	4.32 ± 4.12 [2.83–5.81]	
Subluxation of LM (mid-body)	F	126	2.44 ± 3.61 [1.80–3.08]	0.180
	M	32	3.40 ± 3.54 [2.12–4.68]	
Subluxation of MM (ant. horn)	F	126	1.85 ± 2.19 [1.46–2.24]	0.460
	M	32	2.18 ± 2.37 [1.33–3.03]	
Subluxation of MM (mid-body)	F	126	2.51 ± 2.03 [2.15–2.87]	0.042
	M	32	1.68 ± 2.01 [0.95–2.40]	

subluxation of 1.30 ± 1.72 mm and 2.44 ± 2.14 mm, respectively. For macerated lateral meniscus, the anterior horn and mid-body of the medial meniscus were 2.77 ± 2.55 mm and 2.26 ± 1.98 mm, respectively. This finding indicates that lateral TF OA can affect the medial compartment, and appears to have a greater effect on the anterior horn of the medical meniscus in those with macerated lateral meniscus.

In terms of meniscal height, the lateral meniscus with non-macerated morphology (anterior horn = 5.41 ± 1.98 mm, mid-body = 6.03 ± 1.88 mm) was smaller in height than the medial meniscus of the same cases (anterior horn = 6.35 ± 1.71 mm, mid-body 7.05 ± 1.83 mm). These findings may be due to the fact that lateral TF OA did not have many grade 5 and grade 6 cases compared to medial TF OA. But this was the case only in the anterior horn and mid-body, not in the posterior horn. (Posterior horn of lateral meniscus = 5.66 ± 1.63, posterior horn of medial meniscus = 5.89 ± 0.92.)

The limitations of this study include the following. First, the cohort size (158 knees) was relatively small and different results might have been obtained with a larger study sample. However, based on the low prevalence of lateral OA, one-tenth that of medial OA[26], these results suggest the need for additional research. Second, our study findings cannot be generalized to all lateral OA cases because we used a highly selected sample of severe symptomatic lateral OA scheduled for TKA with no background of trauma, which is likely not representative of lateral knee OA. Third, there is a possibility that the menisci in the subjects might continue to change and become completely destroyed or macerated, which would affect the findings and interpretations of outcomes. Fourth, it is unclear whether the hypertrophied lateral menisci in this series (13 cases at the anterior horn, 11 cases at the mid-body, five cases at the posterior horn) were truly hypertrophied or were the result of destroyed discoid lateral menisci, a common finding in Korea[27,28]. This interpretation would depend on the enrollment of patients with discoid meniscus, which is unknown and would likely lead to different results. Fifth, as histologic analyses were not done in this series, we cannot conclude that lateral compartment OA has various grades of meniscal morphology. However, we believe that our classification, which was based on previous reports[20], can contribute to the understanding of different mechanisms of medial and lateral OA.

Based on the high prevalence of hypertrophied medial meniscus in patients with end-stage medial OA, and the prevalence of macerated lateral meniscus in patients with end-stage lateral OA, other factors such as local biomechanical dynamics and different surrounding structures for each compartment should be considered and investigated to better understand the development and progression of medial and lateral OA. Since macerated meniscus is the final form of lateral OA, morphological changes of the meniscus in prior grades of end-stage lateral OA should be further studied. Based on the results of this study, the final meniscus abnormality of end-stage lateral OA appears to be complete maceration.

Author contributions

All authors made substantial contributions to all of the following: (1) the conception and design of the study, or acquisition of data, or analysis and interpretation of data, (2) drafting the article or revising it critically for important intellectual content, (3) final approval of the version to be submitted.

Conflict of interest

The authors have no conflicts of interest to declare.

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